

INTERNATIONAL COOPERATION TREATY

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Assistant Commissioner for Patents  
United States Patent and Trademark  
Office  
Box PCT  
Washington, D.C. 20231  
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

Date of mailing:

02 September 1999 (02.09.99)

International application No.:

PCT/GB99/00470

Applicant's or agent's file reference:

15251 LgCm

International filing date:

16 February 1999 (16.02.99)

Priority date:

25 February 1998 (25.02.98)

Applicant:

INMAN, Michael et al

1. The designated Office is hereby notified of its election made:



in the demand filed with the International preliminary Examining Authority on:

24 June 1999 (24.06.99)



in a notice effecting later election filed with the International Bureau on:

2. The election ☒ was



was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO  
34, chemin des Colombettes  
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer:

J. Zahra

Telephone No.: (41-22) 338.83.38

## PCT

## INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference <b>15251 LgCm</b>	<b>FOR FURTHER ACTION</b> see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. <b>PCT/GB 99/ 00470</b>	International filing date (day/month/year) <b>16/02/1999</b>	(Earliest) Priority Date (day/month/year) <b>25/02/1998</b>
Applicant <b>AEA TECHNOLOGY PLC et al.</b>		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.



It is also accompanied by a copy of each prior art document cited in this report.

## 1. Basis of the report

- a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.



the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

- b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :



contained in the international application in written form.



filed together with the international application in computer readable form.



furnished subsequently to this Authority in written form.



furnished subsequently to this Authority in computer readable form.



the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.



the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. ☐ **Certain claims were found unsearchable** (See Box I).

3. ☐ **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,



the text is approved as submitted by the applicant.



the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,



the text is approved as submitted by the applicant.



the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No.

2



as suggested by the applicant.



None of the figures.



because the applicant failed to suggest a figure.



because this figure better characterizes the invention.

## Box III TEXT OF THE ABSTRACT (Continuation of item 5 of the first sheet)

A component for gas treatment

A component of dielectric material for use in a gas treatment device in which the gas is exposed to an electric discharge, especially for the formation of a non-thermal plasma. The component is formed with axially extending apertures (19), shaped in cross section to concentrate voltage drop derived from the charged dielectric material in the region where the apertures are narrowest.

## INTERNATIONAL SEARCH REPORT

International Application No.

T/GB 99/00470

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 B01D53/32 F01N3/08 F01N3/28

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 F01N B01D B01J H05B B28B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 98 02233 A (BATTELLE MEMORIAL INSTITUTE) 22 January 1998 see page 3, line 10 - line 33 see page 4, line 25 - page 6, line 10; figures ---	1, 5, 7, 9
A	WO 95 31270 A (KIESER JOERG ;LINS GUENTER (DE); SEEBOECK ROBERT (DE); SIEMENS AG) 23 November 1995 see abstract; figures ---	1, 9
A	US 3 620 703 A (EVANS JAMES W ET AL) 16 November 1971 see column 2, line 58 - column 4, line 62; figures --- -/--	1

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

## \* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

26 May 1999

Date of mailing of the international search report

02/06/1999

Name and mailing address of the ISA

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Authorized officer

Sideris, M

## INTERNATIONAL SEARCH REPORT

International Application No

/GB 99/00470

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
A	US 4 767 309 A (MIZUNO HIROSHIGE ET AL) 30 August 1988 see abstract; figures 1-3 ---	1
A	GB 2 274 412 A (ATOMIC ENERGY AUTHORITY UK) 27 July 1994 cited in the application ---	
A	US 5 009 763 A (HISE RALPH E) 23 April 1991 -----	

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

T/GB 99/00470

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 9802233	A	22-01-1998	NONE	
WO 9531270	A	23-11-1995	DE 9407861 U	19-10-1995
US 3620703	A	16-11-1971	NONE	
US 4767309	A	30-08-1988	JP 1851441 C	21-06-1994
			JP 62297109 A	24-12-1987
			DE 3776817 A	02-04-1992
			EP 0250166 A	23-12-1987
GB 2274412	A	27-07-1994	DE 69314928 D	04-12-1997
			DE 69314928 T	19-03-1998
			EP 0608619 A	03-08-1994
			JP 6241019 A	30-08-1994
			NO 940170 A	21-07-1994
			US 5440876 A	15-08-1995
US 5009763	A	23-04-1991	NONE	

## PCT

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

A

Applicant's or agent's file reference 15251 LgCm	<b>FOR FURTHER ACTION</b>		See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/GB99/00470	International filing date (day/month/year) 16/02/1999	Priority date (day/month/year) 25/02/1998	
International Patent Classification (IPC) or national classification and IPC B01D53/32			
Applicant AEA TECHNOLOGY PLC et al.			

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.


2. This REPORT consists of a total of 5 sheets, including this cover sheet.

- ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 2 sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demand  24/06/1999	Date of completion of this report  03.02.2000
Name and mailing address of the international preliminary examining authority:   European Patent Office D-80298 Munich Tel: +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer  Sembritzki, T  Telephone No. +49 89 2399 8626



**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT**

International application No. PCT/GB99/00470

**I. Basis of the report**

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

**Description, pages:**

1-12 as originally filed

**Claims, No.:**

1,2,3 (part) as originally filed

3 (part),4-8 as received on 15/12/1999 with letter of 12/12/1999

**Drawings, sheets:**

1/8-8/8 as originally filed

2. The amendments have resulted in the cancellation of:

- ☐ the description. pages:  
☐ the claims. Nos.:  
☐ the drawings. sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:



**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT**

International application No. PCT/GB99/00470

**V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

**1. Statement**

Novelty (N)	Yes:	Claims 1-8
	No:	Claims
Inventive step (IS)	Yes:	Claims 1-8
	No:	Claims
Industrial applicability (IA)	Yes:	Claims 1-8
	No:	Claims

**2. Citations and explanations**

**see separate sheet**

**VIII. Certain observations on the international application**

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

**see separate sheet**

**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT - SEPARATE SHEET**

International application No. PCT/GB99/00470

Reference is made to the following documents:

D1: WO 98 02233 A (BATTELLE MEMORIAL INSTITUTE) 22 January 1998

**Re Item V:**

**1. Novelty**

- 1.1 Document D1, which is considered to represent the most relevant state of the art, discloses an apparatus for the treatment of exhaust gas, which comprises an electrode coated with a dielectric material at each end of a monolith having apertures extending therethrough in the flow direction.
- The subject-matter of claim 1 of the present application differs from this apparatus mainly in that the whole component comprises dielectric material, which provides by the design of the apertures an interconnection of those regions which define opposite sides of the narrowest part of the apertures and in that the electric potential is applied transverse to the direction of gas flow.
- The subject-matter of claim 1 is therefore new (Article 33(2) PCT).

**2. Inventive step**

- 2.1 The problem to be solved can be regarded as to provide a gas treatment device which comprises a dielectric material and provides an improved formation of a non-thermal plasma.
- The solution proposed in claim 1 of the present application, i.e. the combination of the design of the apertures with the use of an electric potential applied in a direction transverse to the gas flow, is neither known from nor suggested by the available prior art. Although D1 discloses apertures with "narrowest parts" (see D1, figure 2), the electric potential is not applied between these parts transverse to the gas flow, but between both ends of the whole component along the gas flow.
- The subject-matter of claim 1 of the present application is therefore considered as involving an inventive step (Article 33(3) PCT).

**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT - SEPARATE SHEET**

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International application No. PCT/GB99/00470

2.2 Claims 2-7 and claim 8 related to a reactor comprising a component according to the invention are dependent on claim 1 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

**3. Industrial application**

The industrial applicability is obvious.

orthogonal directions transverse to the said direction of gas flow, a first pair of electrodes is positioned one on one side and the other on the other side of the component so as to be spaced apart from one another in one said  
5 transverse direction, and a second pair of electrodes is positioned one on one side and the other on the other side of the component so as to be spaced apart from one another in the other, orthogonal, transverse direction.

10 4. A component as claimed in claim 1, further characterised in that the said means for applying an electric potential comprise wires (41,42) extending through the dielectric material (13,13a; 16,17; 16a,17a).

15 5. A component as claimed in any of the preceding claims, further characterised in that each aperture (14; 14a; 19; 19a) is shaped in cross-section to taper on both or all sides towards the said narrowest part of the aperture, thereby to encourage transfer of electrical  
20 discharge from the said narrowest part into the tapered parts of the apertures.

6. A component as claimed in any of the preceding claims, further characterised in that the dielectric  
25 material is chosen to have in the presence of an electrical discharge a catalytic action in the reduction of nitrogenous oxides.

7. A component as claimed in any of the preceding  
30 claims, further characterised in that the dielectric material is a barium titanate containing material.

8. A reactor for reducing pollution from exhaust emissions from an internal combustion engine, comprising  
35 a reactor chamber (26) adapted to form part of an internal combustion engine exhaust system, characterised

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in that the reactor chamber (26) includes a component (25) as claimed in any of the preceding claims, through which component (25) exhaust gases are constrained to pass.

## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification<sup>6</sup> :

B01D 53/32, F01N 3/08, 3/28

A1

(11) International Publication Number:

WO 99/43419

(43) International Publication Date:

2 September 1999 (02.09.99)

(21) International Application Number: PCT/GB99/00470

(22) International Filing Date: 16 February 1999 (16.02.99)

(30) Priority Data:

9803817.7

25 February 1998 (25.02.98)

GB

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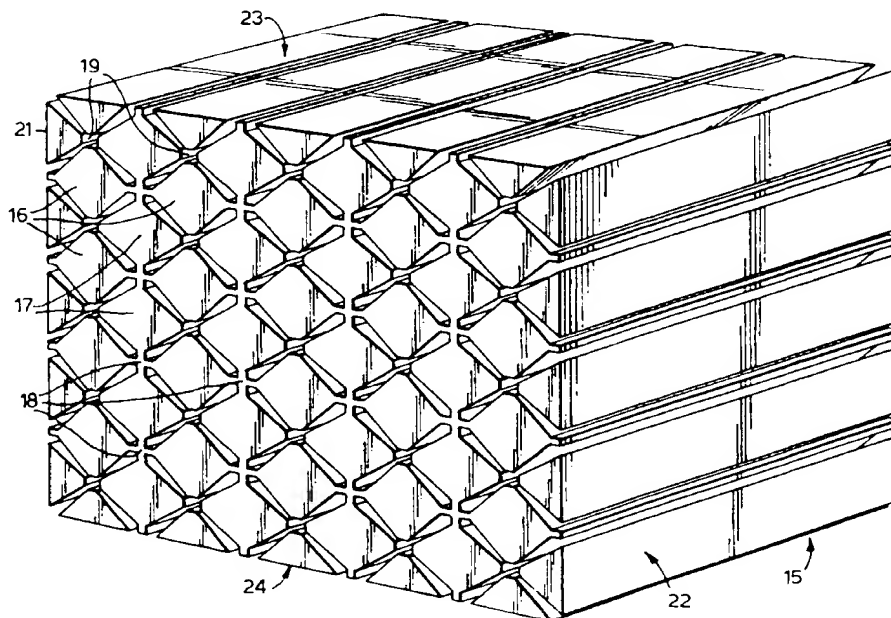
(74) Agents: LOFTING, Marcus, John et al.; AEA Technology plc, Patents Dept., 329 Harwell, Didcot, Oxfordshire OX11 0RA (GB).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published

With international search report.

(54) Title: A COMPONENT FOR GAS TREATMENT



## (57) Abstract

A component of dielectric material for use in a gas treatment device in which the gas is exposed to an electric discharge, especially for the formation of a non-thermal plasma. The component is formed with axially extending apertures (19), shaped in cross section to concentrate voltage drop derived from the charged dielectric material in the region where the apertures are narrowest.

A component for gas treatment

The present invention relates to a component for the treatment of gases, and in particular to a component for exposing gas to a non-thermal plasma, desirably in the presence of a catalyst. More specifically, the invention relates to a component incorporated in a reactor for the reduction of polluting components such as carbonaceous and nitrogenous combustion products emitted in the exhaust of internal combustion engines.

One of the major problems associated with the development and use of internal combustion engines is the noxious exhaust emissions from such engines. Two of the most deleterious materials, particularly in the case of diesel engines, are particulate matter (primarily carbon) and oxides of nitrogen ( $\text{NO}_x$ ). Increasingly severe emission control regulations are forcing internal combustion engine and vehicle manufacturers to find more efficient ways of removing these materials in particular from internal combustion engine exhaust emissions. Unfortunately, in practice, it is found that combustion modification techniques which improve the situation in relation to one of the above components of internal combustion engine exhaust emissions tend to worsen the situation in relation to the other. Even so, a variety of systems for trapping particulate emissions from internal combustion engine exhausts have been investigated, particularly in relation to making such particulate emission traps capable of being regenerated when they have become saturated with particulate material.

Examples of such diesel exhaust particulate filters are to be found in European patent application EP 0 010

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384; US patents 4,505,107; 4,485,622; 4,427,418; and  
4,276,066; EP 0 244 061; EP 0 112 634 and EP 0 132 166.

In all the above cases, the particulate matter is  
5 removed from diesel exhaust gases by a simple physical  
trapping of particulate matter in the interstices of a  
porous, usually ceramic, filter body, which is then  
regenerated by heating the filter body to a temperature  
at which the trapped diesel exhaust particulates are  
10 burnt off. In most cases the filter body is monolithic,  
although EP 0 010 384 does mention the use of ceramic  
beads, wire meshes or metal screens as well. US patent  
4,427,418 discloses the use of ceramic coated wire or  
ceramic fibres.

15

In a broader context, the precipitation of charged  
particulate matter by electrostatic forces also is known.  
However, in this case, precipitation usually takes place  
upon large planar electrodes or metal screens.

20

GB patent 2,274,412 discloses a method and apparatus  
for removing particulate and other pollutants from  
internal combustion engine exhaust gases, in which the  
exhaust gases are passed through a bed of charged pellets  
25 of material, preferably ferroelectric, having high  
dielectric constant. In addition to removing  
particulates by oxidation, especially electric discharge  
assisted oxidation, there is disclosed the reduction of  
NO<sub>x</sub> gases to nitrogen, by the use of pellets adapted to  
30 catalyse the NO<sub>x</sub> reduction.

The use of a reactor comprising a bed of beads of  
spherical, pellet, chip or other suitable form presents a  
problem, particularly for motor vehicles, in that the  
35 beads tend to wear or break up under the attrition to



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which they are subjected in use. Whilst monoliths of foam or honeycomb configuration can be adopted, we have found satisfactory formation of a non-thermal plasma is difficult to achieve with known forms of these configurations.

It is an object of the present invention to provide a gas permeable component of dielectric material, which may be, or may be combined with, a catalytic material, for the treatment of gas, in a form which can be extruded or otherwise formed into a monolithic structure, and which will effectively support the formation of a non-thermal plasma when subjected to an electric potential.

The invention provides, in one of its aspects, a component for use in a gas treatment device, which component comprises dielectric material having apertures extending therethrough in a direction of gas flow through the component when in use, the apertures having a re-entrant configuration in cross-section and being such that there is interconnection through dielectric material of those regions of dielectric material which define opposite sides of the narrowest part of the apertures as measured in at least one direction transverse to the said direction of gas flow, and means for applying an electric potential across the component in the said transverse direction, or one of the said transverse directions, whereby the voltage drop across the said narrowest part of the apertures is greater than the voltage drop thereacross would be if the aperture were filled with the dielectric material.

For the purpose of providing the electric potential, a pair of electrodes is positioned one on one side and the other on the other side of the component so as to be

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spaced apart from one another in the said transverse direction, or one of the said transverse directions.

In one arrangement according to the invention, the  
5 apertures are shaped to provide interconnection through dielectric material of those regions of dielectric material which define opposite sides of the narrowest part of the apertures as measured in two mutually  
10 orthogonal directions transverse to the said direction of gas flow, a first pair of electrodes is positioned one on one side and the other on the other side of the component so as to be spaced apart from one another in one said transverse direction, and a second pair of electrodes is  
15 positioned one on one side and the other on the other side of the component so as to be spaced apart from one another in the other, orthogonal, transverse direction.

In an alternative arrangement embodying the invention, the said means for applying an electric  
20 potential comprise wires(41,42) extending through the dielectric material(13,13a;16,17;16a,17a).

The apertures are such as to promote formation of a non-thermal plasma therein when the component is in use  
25 and an electric potential is applied. For this purpose, for example, each aperture is shaped in cross-section to taper on both or all sides towards the said narrowest part of the aperture, thereby to encourage transfer of electrical discharge from the said narrowest part into  
30 the tapered parts of the apertures.

Preferably the dielectric material is chosen to have in the presence of an electrical discharge a catalytic action in the reduction of nitrogenous oxides.

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Preferably the dielectric material is a barium titanate containing material.

The invention provides, in another of its aspects, a  
5 reactor for reducing pollution from exhaust emissions  
from an internal combustion engine, comprising a reactor  
chamber adapted to form part of an internal combustion  
engine exhaust system, the reactor chamber including a  
component as aforesaid, through which component exhaust  
10 gases are constrained to pass.

Specific constructions of component and reactor  
embodying the invention will now be described by way of  
example and with reference to the drawings filed  
15 herewith, in which:

Figure 1 is a perspective view of part of a  
component,

20 Figure 2 is a perspective view of part of another  
component,

Figures 3, and 4, are diagrammatic representations  
of alternative cross-sectional shapes for the component,  
25

Figure 5 is a diagrammatical representation of a  
reactor incorporating a component according to the  
invention,

30 Figure 6 shows a modification of the component of  
Figure 2, and

Figures 7 to 9 show further variants of the  
modification shown in Figure 6.

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Figure 1 shows a component 10 which can be formed by extrusion from a dielectric material 11. Our preferred material is one containing barium titanate which, for extrusion purposes, may be fabricated from a barium titanate powder together with a binder of for example alumina, silica or titania or a combination of these, for example a combination of silica and titania.

As may be seen from Figure 1, the extrusion has the form of a series of parallel plates 12 between which, and integral with which, is a matrix of rods 13 of generally rhombus shape in cross-section extending parallel with one another between the plates 12 along the length of the component 10.

The series of rods 13 between each pair of plates 12 provides a corresponding series of apertures 14 extending along the length of the component 10 and having a shape in cross-section like that of a stylised bow tie.

Electrodes (not shown) positioned on the respective two sides of the component 10 perpendicular to the plane of the plates 12 enable an electric potential to be applied to the component in a direction parallel with the plates 12 and transverse to the length of the apertures 14.

The re-entrant shape of the apertures 14 in cross-section has the effect that voltage drop derived from the charged dielectric material is concentrated in the region where the space between one rod 13 and its adjacent rod is narrowest. This configuration has the effect of promoting the formation of non-thermal plasma in these narrow spaces. However, it is a feature of plasma formed in this way that it tends to expand and travel along outwardly tapering spaces which communicate with the

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narrow space where plasma tends to be initiated. The shape of the apertures 14 is thus conducive to the formation of plasma which fills the entire void space of the component 10.

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A feature of the configuration shown in Figure 1 is that the plates 12 provide a continuous dielectric path between the electrodes and between each such path there is a series of discharge gaps provided by the narrowest part of the apertures 14, the discharge gaps being aligned to be parallel with the electric field set up between the electrodes.

Figure 2 illustrates another configuration in which component 15 can be formed by extrusion. Again, the configuration is based upon an array of generally rhombus shaped rods 16,17. Alternate rows and columns of the rods 16, 17 are joined at their apices by cruciform regions 18. The intervening rows and columns provide a series of discharge gaps 19. The rods 16, 17 are so shaped that the narrow spaces between adjacent rods which communicate with the discharge gaps 19 are tapered, with the narrowest region of the taper at the gaps 19. As explained above, this promotes the transfer of plasma formed in the discharge gaps 19 along the tapered spaces. It will be seen that adjacent each aligned row of discharge gaps 19 is an aligned row of interconnected rods 16. Similarly, adjacent to each aligned column of discharge gaps 19 is an aligned column of interconnected rods 17.

Electrodes (not shown) covering respectively the sides 21 and 22 of the component 15 enable an electrical potential to be applied across the component 15. By virtue of the juxtaposition of interconnected rods 16 in one row and cross connected rods 17 with intervening

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discharge gaps 19 in the adjacent row, application of an appropriate electrical potential in this way leads to the generation of plasma discharge in the gaps 19 and expansion of the plasma into the tapering spaces to fill  
5 the entire void structure of the component 15.

It will be apparent from the symmetry of the component shown in Figure 2, that electrodes (not shown) may be positioned to cover the sides 23 and 24  
10 respectively so as to enable an electrical potential to be applied parallel with the columns of rods 16, 17. Provided there is an appropriate insulating gap between electrodes on the adjacent sides which may at any instant be at a different potential, electrical excitation may be  
15 applied to all four sides.

It will be appreciated that controlled arrays of discharge gaps between regions of dielectric material interconnected to concentrate potential drop across the  
20 discharge gaps can be achieved with a variety of different configurations of extruded matrix. Figure 3 shows a variant of the Figure 2 configuration, similar components bearing the same reference numerals distinguished by the suffix "a". Figure 4 shows a  
25 variant of the Figure 1 configuration, based upon cylindrical rods. The reference numerals used in Figure 4 correspond with those of Figure 1, distinguished by the suffix "a".

30 Figure 5 shows diagrammatically in cross-section a component 25 comprising an extruded monolith having a configuration (chosen as discussed further below) as shown in one of the Figures 1 to 4 and incorporated in a plasma reactor for the purification of internal  
35 combustion engine exhaust emissions.

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The component 25 is mounted within a cylindrical stainless steel chamber 26 which is arranged to be connected to an earthing point at 27 and which has an inlet nozzle 28 by means of which it can be connected to the exhaust system of an internal combustion engine, and a similar outlet nozzle 29. Exhaust gas flows as indicated by the arrows A axially through the apertures of the component 25.

Because of the cylindrical geometry, it is necessary for the extruded monolith component 25 to have a symmetrical configuration such as that of Figure 2 cut or shaped into a cylinder with an axial bore 31. The axial bore 31 is closed at each end to ensure all gas flow is through the apertures of the monolith component 25. An outer electrode is provided either by the chamber 26 itself or by a cylindrical metallic sheath on the component 25 and in electrical contact with the chamber 26. An inner electrode 32 is provided in the form of a cylindrical lining for the bore 31. The electrode 32 is connected via a high tension lead-through 10 to a source 9 of electrical potential sufficient to excite a plasma in the exhaust gases in the void spaces within the component 25. A convenient potential for this purpose is a potential of about 10 kV to 30 kV, which may be a pulsed direct potential or a continuously varying alternating potential, or may be an interrupted continuous direct potential. Typically we employ a potential of 20 kV per 30 mm of bed depth.

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In a modified arrangement, in which any of the configurations of Figure 1,2,3, or 4 may be employed, the chamber 26 and component 25 are rectangular in cross section. For this configuration, it is not necessary to have a central bore corresponding to the bore 31. Electrodes may be positioned on opposed sides of the

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component 25, but in this case it is necessary to provide electrical insulation between the high voltage electrode and the chamber 26. For this reason, it may be preferable to provide the high voltage electrode as a sheet positioned centrally within the component 25.

The material of the component 25 is chosen in order to meet the requirements of formation by extrusion, and the dielectric and catalytic properties for the purpose of reducing pollutants from internal combustion engine exhaust gases. The material is preferably a ferroelectric material such as barium titanate or calcium titanate which, for extrusion, will need to be prepared in powder form into which a binder material is incorporated. Gamma alumina, silica or titania or a combination of these may serve as a binder, although a preferred binder is a combination of silica and titania which may be derived from a silica-titania gel. The ferroelectric material may be mixed with a dielectric material such as zirconia or titania, or zeolite for example metal exchanged zeolite or proton exchanged zeolite for example Cu-exchanged ZSM-5 or H-exchanged ZSM-5 or, for some applications, it may be appropriate to use dielectric material alone or mixtures of dielectric materials. Where titania is used, it is advantageous to use the anatase phase in order to benefit from the photocatalytic properties of the material in this form. Other materials such as alumina or a perovskite may be incorporated for the catalytic properties which they impart to the product matrix.

Figure 6 shows a modification of the component of Figure 2 in which a number of the rods 16 are formed with an electrically conducting wire extending through the centre of the rod as indicated diagrammatically on the Figure at 41,42.



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With such an arrangement it is possible to apply an electric field across the gaps 19 in a more individually controlled manner. Referring to Figure 6 the wires represented at 41 marked with a cross are connected to one pole of the voltage power supply (for example the positive pole) whilst those wires represented at 42 with a central dot are connected to the other pole (for example the negative pole). With such a configuration, the electric field established across the gaps 19 will be in a direction substantially parallel with the sides 21 and 22 of component.

It will be appreciated that a variety of different configurations of the positive and negative connections are possible. Figure 7 shows a variant equivalent to that of Figure 6 turned through 90 degrees, i.e. so that the electric field in the gaps 19 extends in a direction substantially parallel with the sides 23 and 24 of the component. Figure 8 shows a variant in which the electric field in the gaps 19 will have components both parallel to the sides 23, 24 and to the sides 21, 22. Figure 9 shows the variant in which the electric field in the gaps 19 will extend in a diagonal direction.

Connection of such a multiplicity of electrodes to the power supply is evidently less straightforward than the use of simple plate electrodes positioned on opposite sides of the component. However, connection may be made via a suitably shaped electrically conducting grids providing connection at one end of the component to the

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wires 41 which are to be positive and at the other end of the component to the wires 42 which are to be negative.

The voltage to be applied across the wires in these  
5 examples will be significantly less than that required  
across electrode plates which are spaced apart by the  
entire width of the component. A typical voltage  
required is likely to be of the order of 3 kV or 4 kV,  
but the value required would have to be determined in the  
10 light of operational experience to be such as to avoid  
failure due to operating beyond the dielectric breakdown  
voltage of the material whilst being sufficient to create  
the desired non-thermal plasma in the gaps 19.

Claims

1. A component for use in a gas treatment device, which component comprises dielectric material (12,13; 12a,13a; 5 16,17; 16a,17a) having apertures(14; 14a;19; 19a) extending therethrough in a direction of gas flow through the component when in use, characterised by the combination of features that the apertures(14; 14a; 19; 19a) have a re-entrant configuration in cross-section and 10 are such that there is interconnection through dielectric material of those regions of dielectric material which define opposite sides of the narrowest part of the apertures(14; 14a; 19; 19a) as measured in at least one direction transverse to the said direction of gas flow, 15 and means is provided for applying an electric potential across at least part of the component in the said transverse direction, or one of the said transverse directions, whereby the voltage drop across the said narrowest part of the apertures (14; 14a; 19; 19a) is 20 greater than the voltage drop thereacross would be if the aperture were filled with the dielectric material.
2. A component as claimed in claim 1, further characterised in that the said means for applying an 25 electric potential comprise a pair of electrodes positioned one on one side and the other on the other side of the component so as to be spaced apart from one another in the said transverse direction, or one of the said transverse directions.
- 30 3. A component as claimed in claim 1, further characterised in that the apertures (14; 14a; 19; 19a) are shaped to provide interconnection through dielectric material of those regions of dielectric material which 35 define the opposite sides of the narrowest part of the apertures(14;14a;19;19a) as measured in two mutually

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orthogonal directions transverse to the said direction of gas flow, a first pair of electrodes is positioned one on one side and the other on the other side of the component so as to be spaced apart from one another in one said  
5 transverse direction, and a second pair of electrodes is positioned one on one side and the other on the other side of the component so as to be spaced apart from one another in the other, orthogonal, transverse direction.

10 4. A component as claimed in claim 1, further characterised in that the said means for applying an electric potential comprise wires (41,42) extending through the dielectric material (13,13a; 16,17; 16a,17a).

15 5. A component as claimed in any of the preceding claims, further characterised in that the said apertures (14; 14a; 19; 19a) are such as to promote formation of a non-thermal plasma therein when the component is in use and an electric potential is applied.

20 6. A component as claimed in any of the preceding claims, further characterised in that each aperture (14; 14a; 19; 19a) is shaped in cross-section to taper on both or all sides towards the said narrowest part of the  
25 aperture, thereby to encourage transfer of electrical discharge from the said narrowest part into the tapered parts of the apertures.

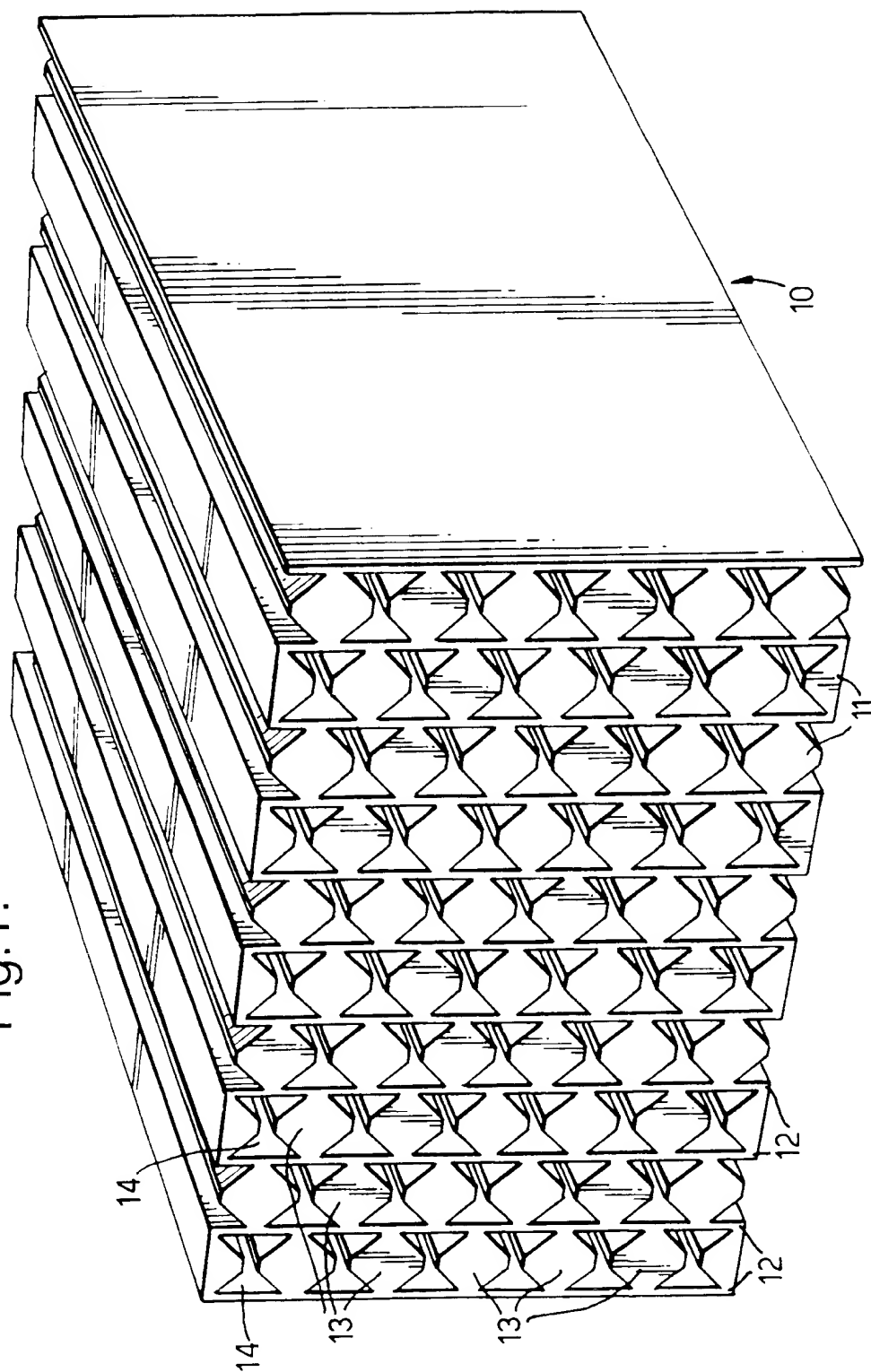
30 7. A component as claimed in any of the preceding claims, further characterised in that the dielectric material is chosen to have in the presence of an electrical discharge a catalytic action in the reduction of nitrogenous oxides.

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8. A component as claimed in any of the preceding claims, further characterised in that the dielectric material is a barium titanate containing material.

- 5 9. A reactor for reducing pollution from exhaust emissions from an internal combustion engine, comprising a reactor chamber (26) adapted to form part of an internal combustion engine exhaust system, characterised in that the reactor chamber (26) includes a component
- 10 (25) as claimed in any of the preceding claims, through which component (25) exhaust gases are constrained to pass.

Fig.1.



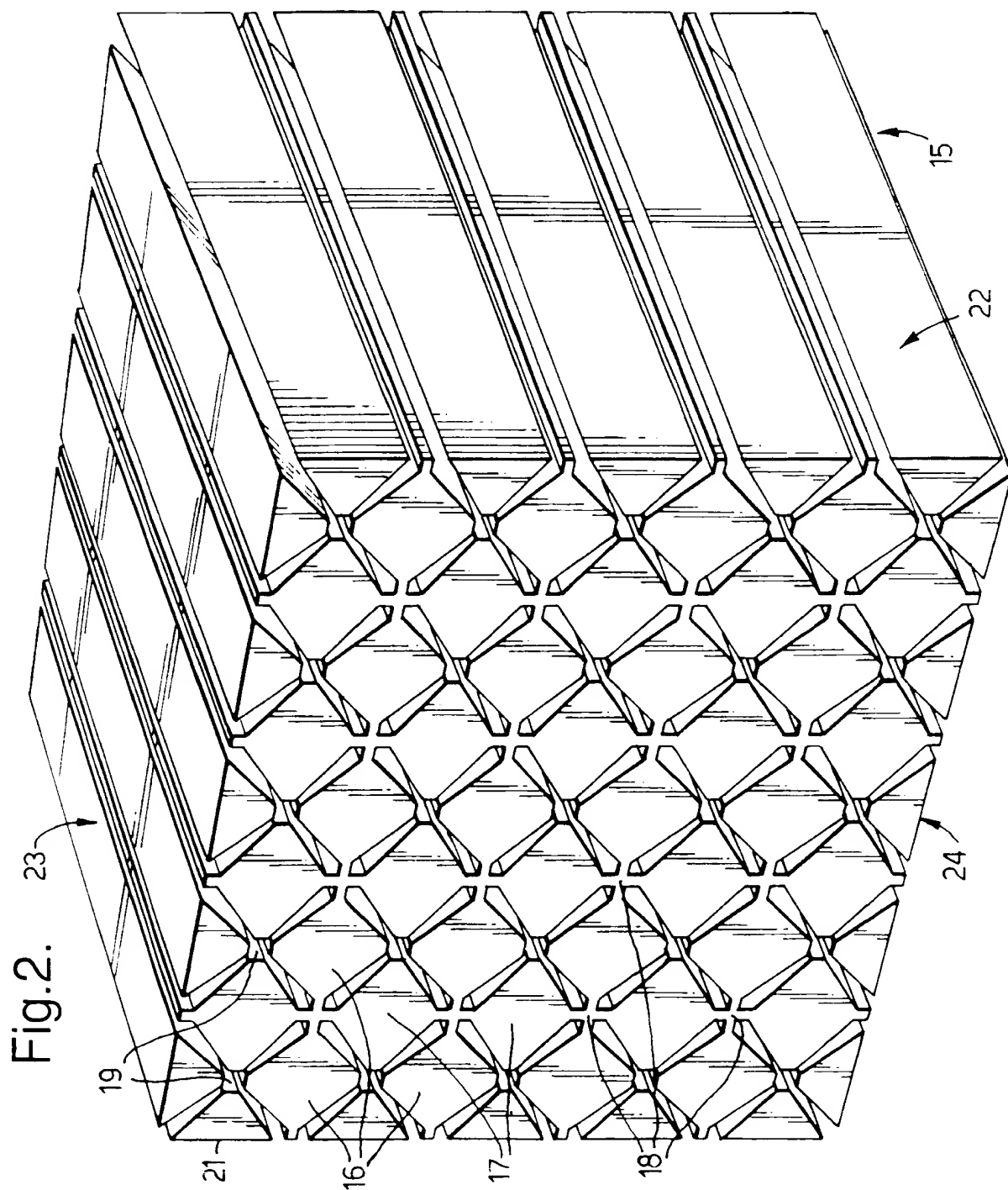


Fig.3.

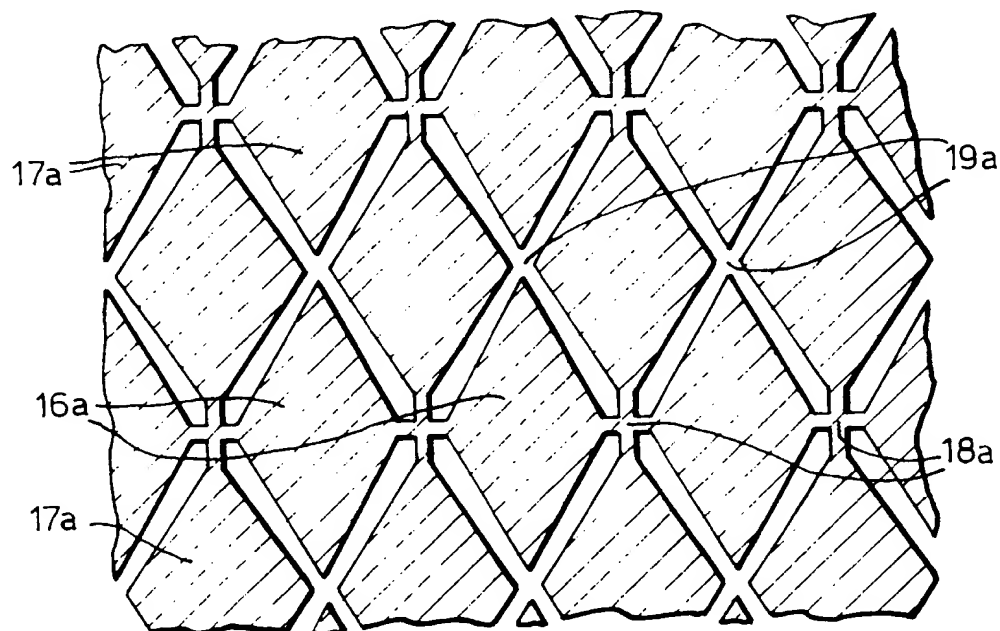


Fig.4.

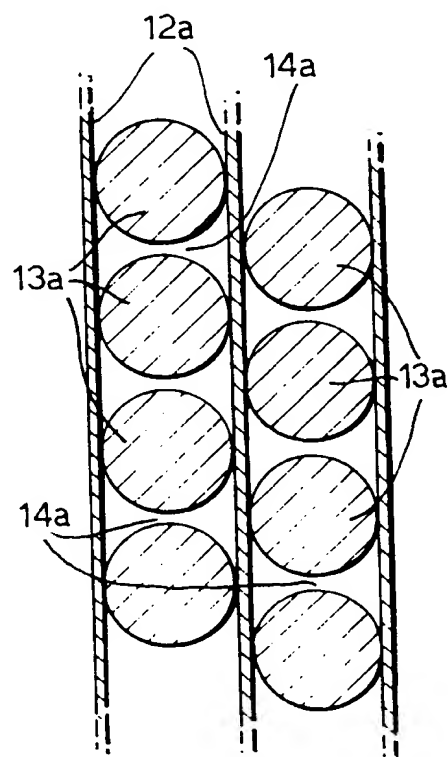
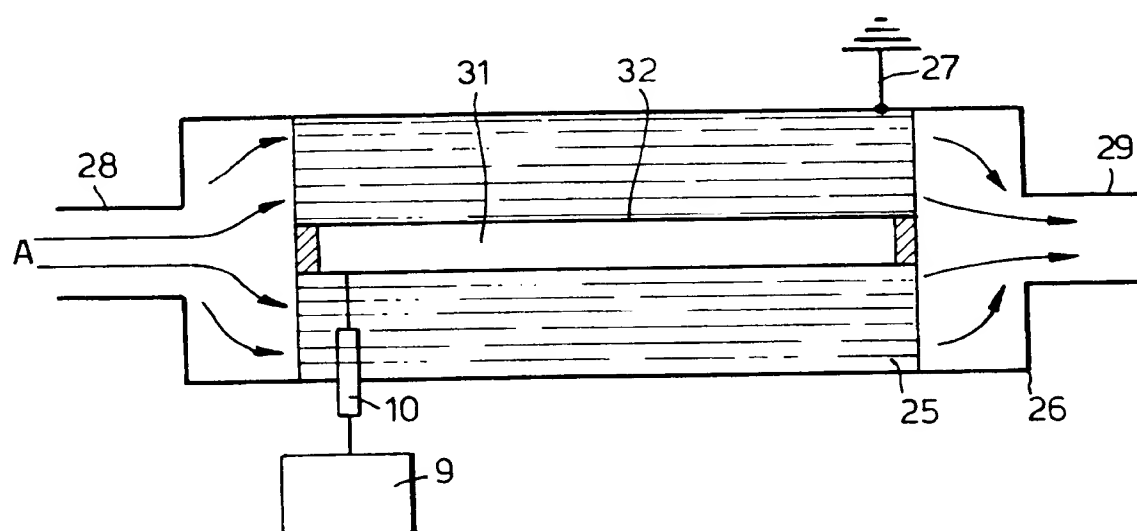
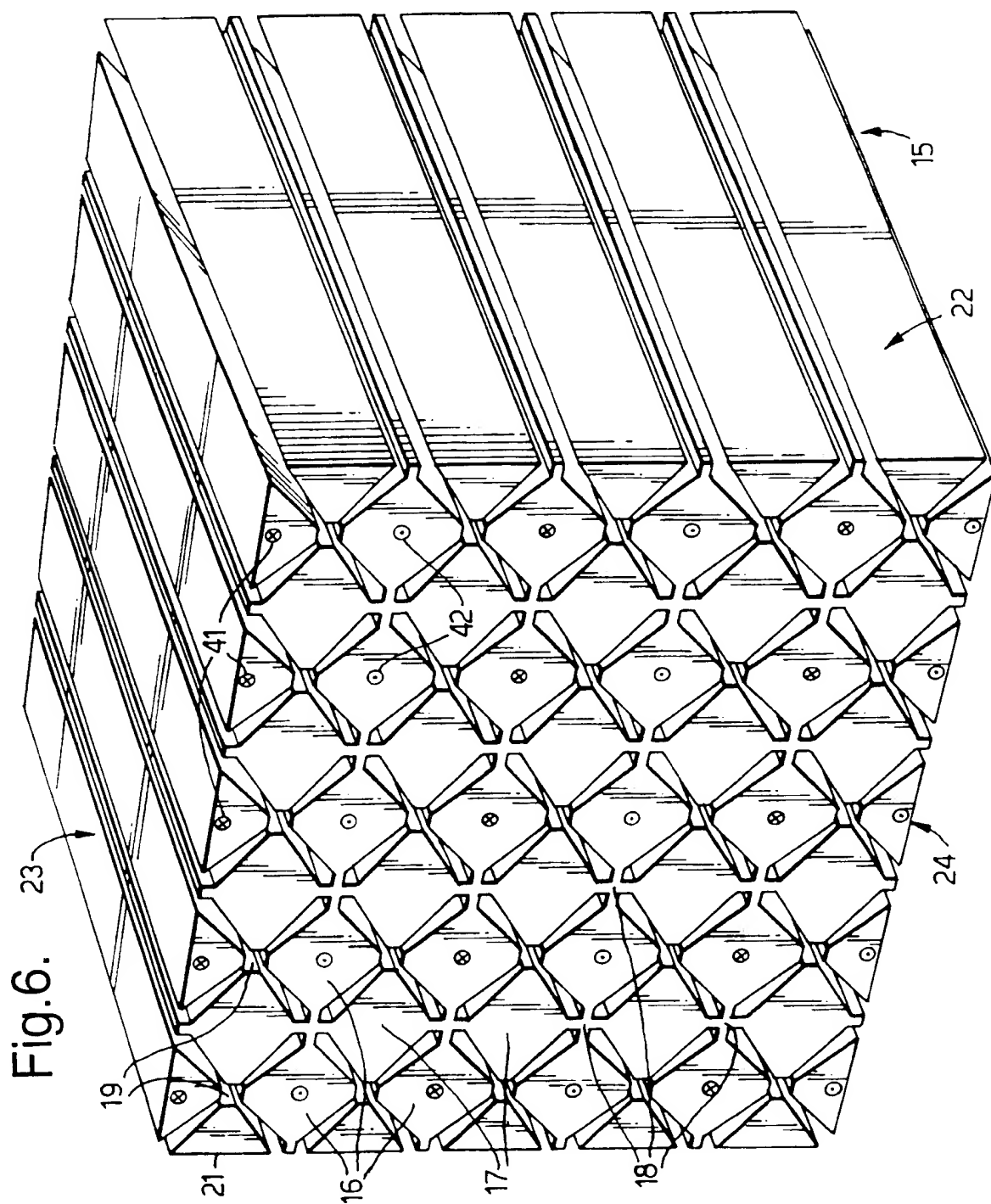
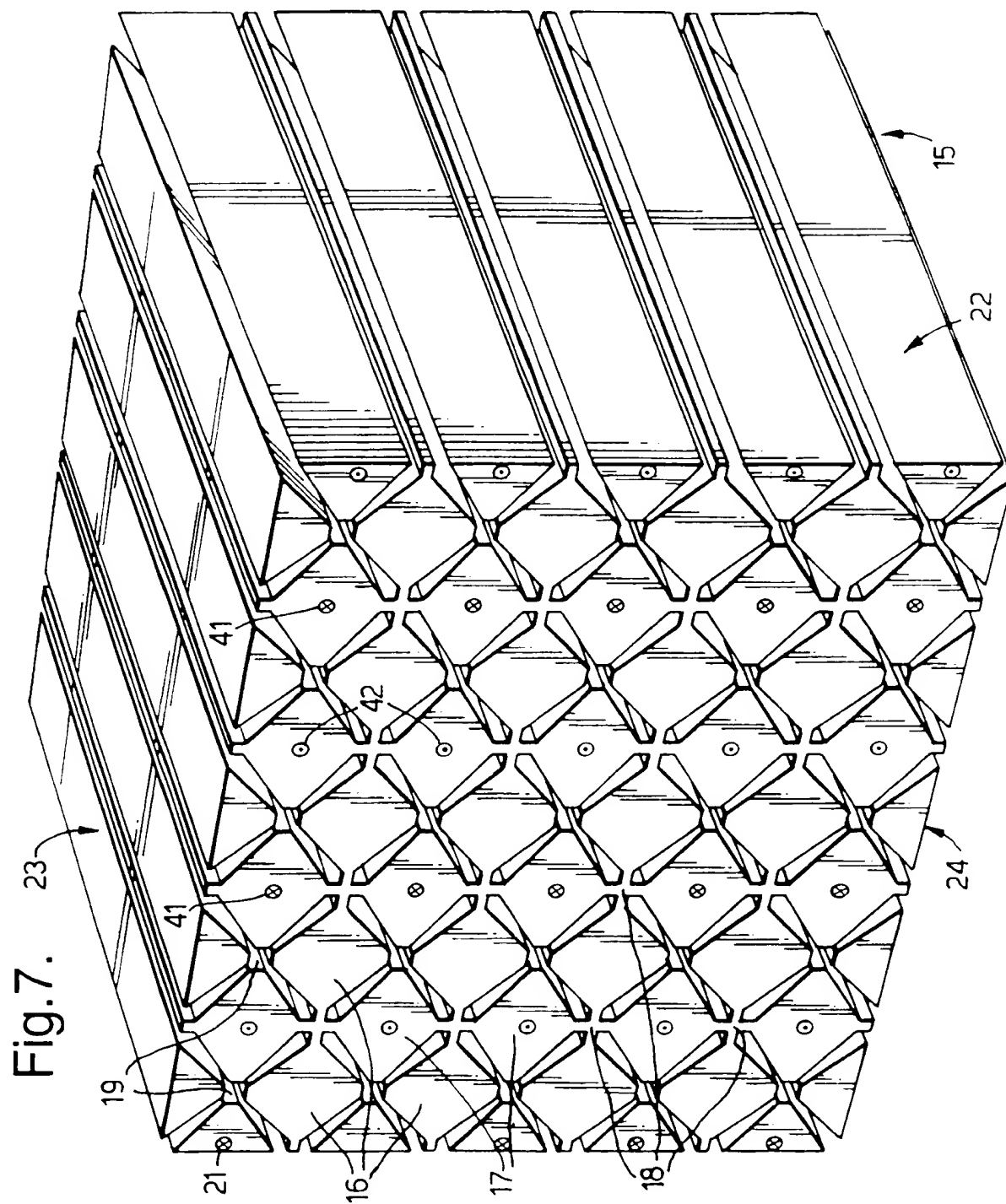


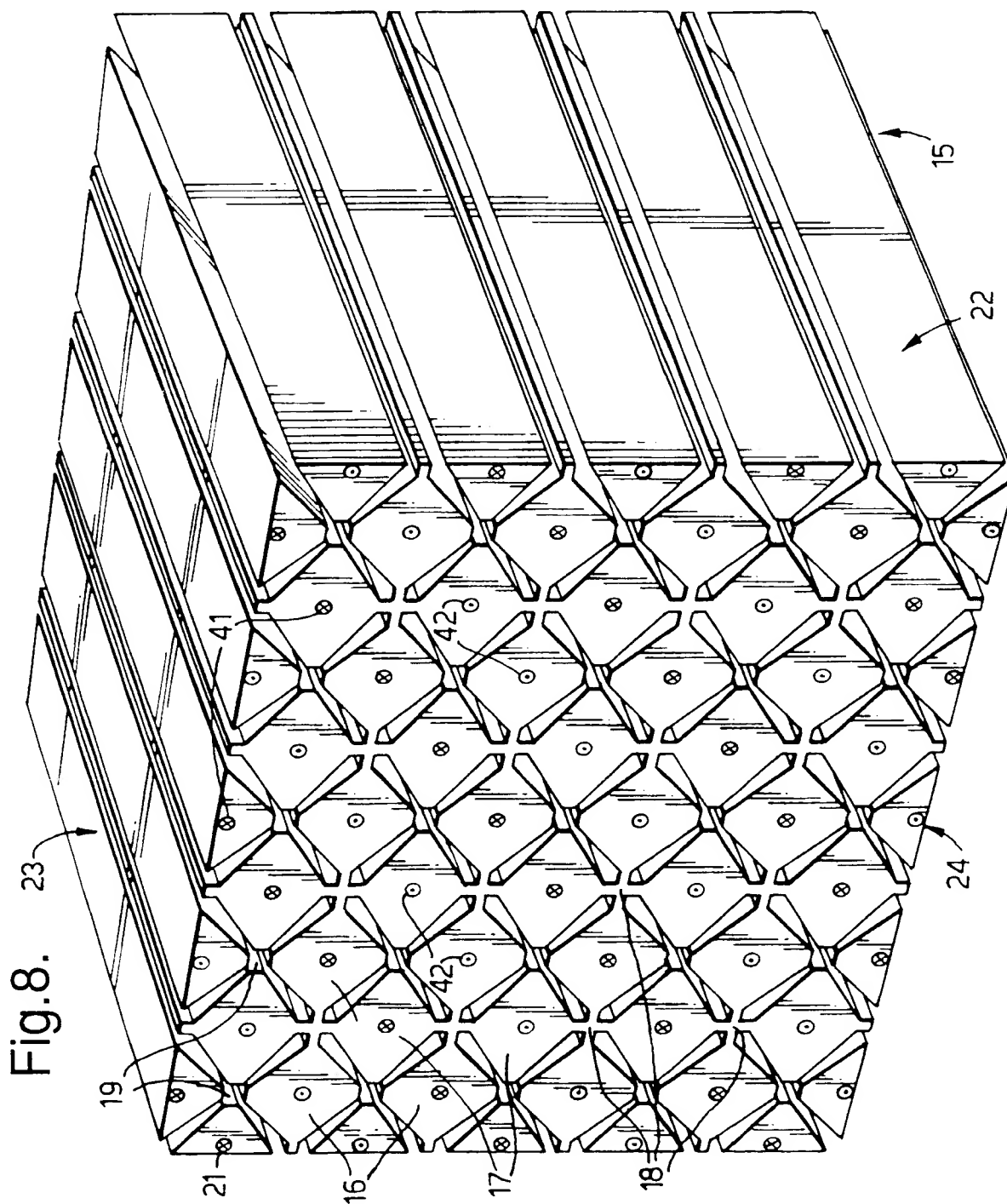


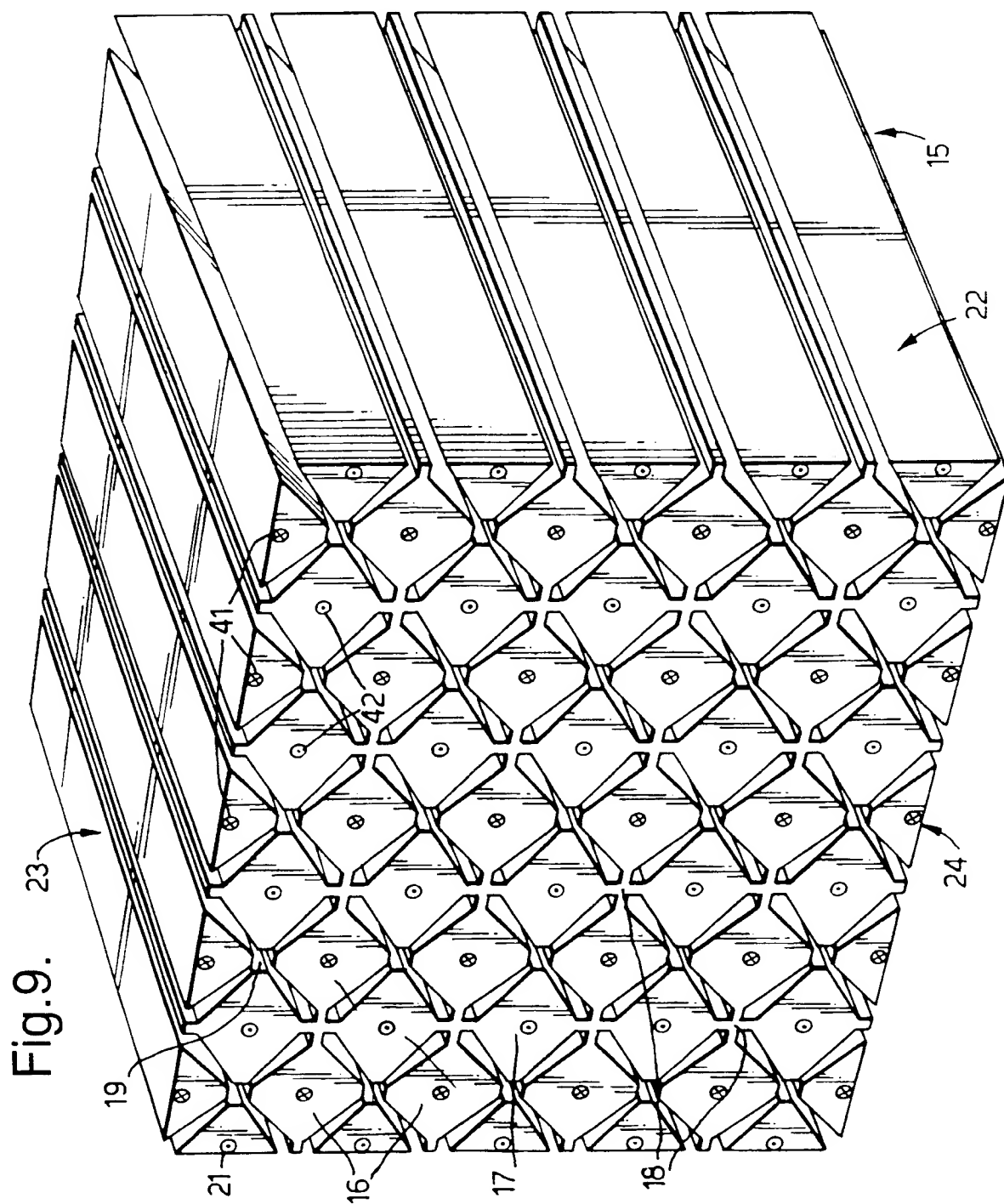
Fig.5.











## INTERNATIONAL SEARCH REPORT

International Application No.

PCT/GB 99/00470

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 B01D53/32 F01N3/08 F01N3/28

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 F01N B01D B01J H05B B28B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	WO 98 02233 A (BATTELLE MEMORIAL INSTITUTE) 22 January 1998 see page 3, line 10 - line 33 see page 4, line 25 - page 6, line 10; figures ---	1,5,7,9
A	WO 95 31270 A (KIESER JOERG ; LINS GUENTER (DE); SEEBOECK ROBERT (DE); SIEMENS AG) 23 November 1995 see abstract; figures ---	1,9
A	US 3 620 703 A (EVANS JAMES W ET AL) 16 November 1971 see column 2, line 58 - column 4, line 62; figures --- -/-	1

☒ Further documents are listed in the continuation of box C☒ Patent family members are listed in annex

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Date of the actual completion of the international search

26 May 1999

Date of mailing of the international search report

02/06/1999

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# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/GB 99/00470

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication where appropriate of the relevant passages	Relevant to claim No
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